ON THE DEVELOPMENT OF EQUITABLE GRAPHIC I/O

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ABSTRACT

The desire for direct interaction between man and machine has led to the study of computer interpretation of free-hand motions of a stylus and the "real-time" responses to these motions. An operating environment is discussed, utilizing elements of pictorial and verbal languages.

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Using the broad capabilities of modern displays, information--text, drawings, and even motion--can be structured so that a computer can communicate it to man in a manner which is direct and natural to the man. However, this communication coin has two sides. The same descriptive powers should exist for input as for output. Or, ideally, if the display is considered as a common working area, then it might suffice as the complete communication medium. The user should be able to create and manipulate the contents of the display in ways which are, again, directly meaningful and natural to him. In many cases, only Graphic I/O systems are sufficiently two-dimensional and dynamic to permit this directness.

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Consider the simple problem of inserting a word into a line of text. With an ordinary typewriter, commands must be given to an intermediary, as follows: "In line 7 before the third word, insert word x..." (or some suitable encoding of that statement). Whereas, if the text appears as a dynamic picture on a display then, with appropriate controls, the user may insert the word directly as easily as on a paper draft. However, these actions--the elements of a graphic input language--must be interpretable by the machine if they are to be operationally meaningful.

Behind the development of graphic language elements are two major issues:

1) The hardware facilities which allow a user to express himself freely in a language both natural to himself and compatible with output capabilities.

2) The interpretive capabilities which make these expressions meaningful.

Much previous research is applicable to these needs. Recognition of handwritten symbols [1-3] has been reasonably successful. The "Sketchpad" effort [4] and its successors developed ways to structure pictorial information so that contextual meaning can be given to external actions on the pictorial information. Recently developed

hardware now accepts free-hand input, providing high-detail data compatible with output capabilities [5].

The present state-of-the-art is such that we can begin to refine these techniques toward their aggregation within one operational system. Such an experimental system (called GRAIL--Graphic Input Language) is under development at The RAND Corporation.* This Paper reports only the nature of this project with respect to man-machine communications and some of the related experiences. It is too early to state measurements or conclusions.

Figure 1 shows the console configuration. It includes a vertical cathode ray tube (CRT) display for output and a horizontal Tablet with pen for communicating free-hand motions to a computer. The computer controls the information on the display surface except for one spot of light. This spot follows the relative pen position on the Tablet at all times. Conceptually, this spot on the CRT is the pen point. A switch in the pen tip senses downward pressure applied to the pen; such action signals the computer program to accept the pen track data and interpret it in the context of the information currently being displayed.

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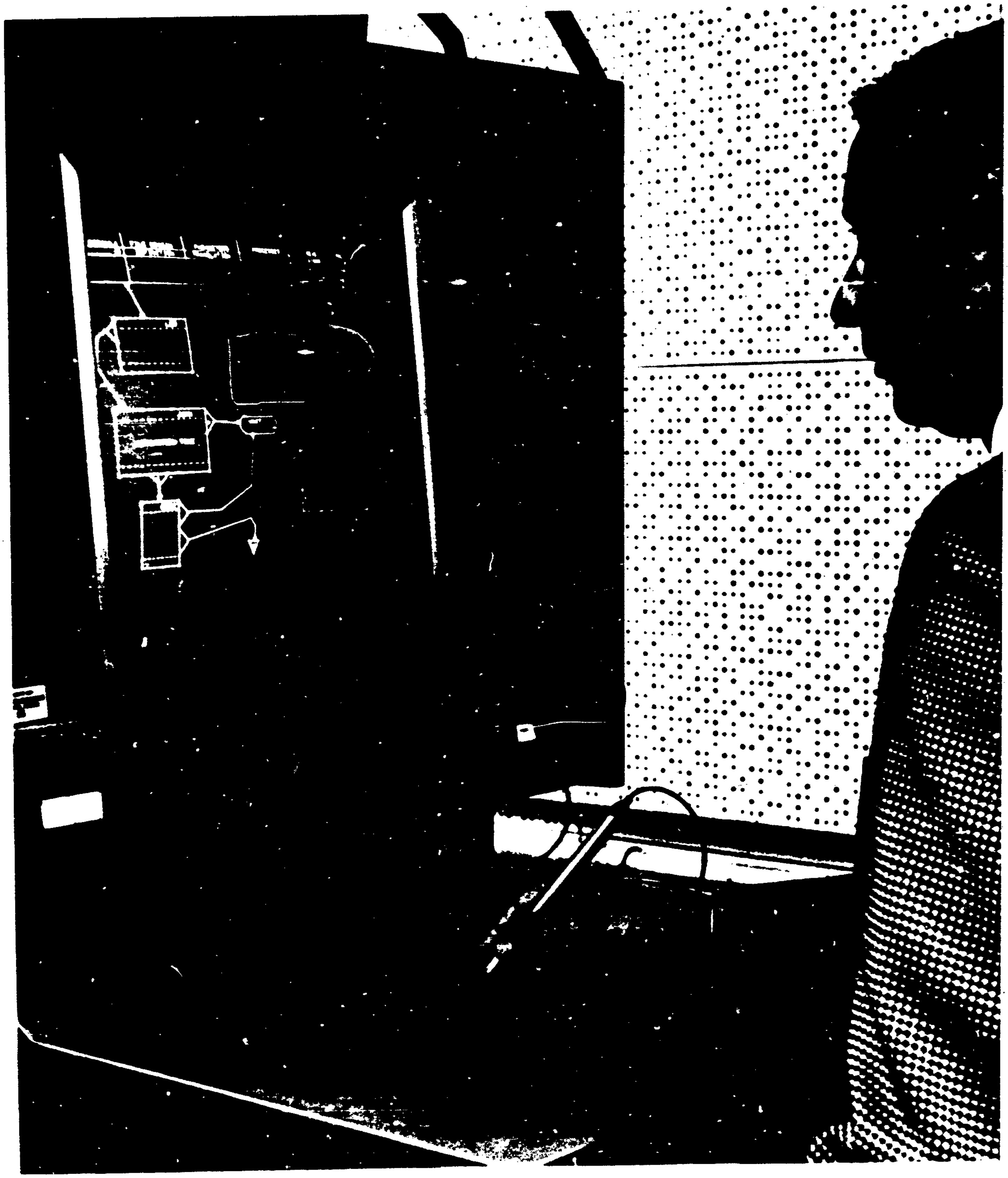

Fig. 1--A User Interacting With the Console

Thus, the user can describe position, symbols, shapes, or motion directly in place, as if he were actually writing on the surface of the CRT. Hence, the user's eyes are always focused on the CRT which is his "working surface." When adding or changing a symbol in the displayed picture, he draws or prints that symbol by applying normal writing pressure during movement to define the separate strokes within the symbol. The immediate computer interpretation represents the path as a visible track on the CRT. This first feedback not only provides the "ink" necessary to the user's ability to draw, but also gives the user real-time indication of exactly what is being interpreted. When this track has described an interpretable symbol, it is replaced (in place) by a normalized symbol. Again, the user can immediately and directly compare his intentions and the computer's interpretation. A major project task is to provide this kind of feedback at each level of interpretation.

The degree of directness of interaction attainable here depends entirely upon the sophistication of the processes available to interpret relatively natural language elements and relate them to the problem context in real time (user time). Processes have been developed

which allow flowchart pictures to be constructed and manipulated with a fixed set of recognizable symbols. These symbols may be drawn, at the user's pace, in the desired position and size. When the pen is lifted at the end of each symbol description, the computer immediately replaces that free-hand track display with a normalized or drafted figure whose type, size, and position are the result of the analysis of that track and its logical implications in the current display. Picture-editing features include the abilities to move, stretch, or erase elements of the picture--again, entirely through pen motion.

In its current state, the symbol-recognition scheme, though imperfect, is productive and constantly being improved.* The recognizable symbol set includes, in addition to the flowchart figures, the upper-case Latin alphabet, Arabic numbers, the symbols +, -, =, /, (,), [,], *, $, ., ,, ', and the text-editing marks >, Λ, and "scrub" (erasure). Again, when a symbol is recognized, a "hardware"-generated symbol replaces the user's inked version. Since the user may change an existing symbol at

*Reference 6 describes and gives early test results of this recognition method.

any time by writing over it, and can insert or delete easily with the above editing marks, his tolerance of recognition errors is generally high. Figure 2 indicates system tolerance of user variations. Text-editing processes allow the above alphanumerics to be used as either designations or comments in the flowchart drawings as well as in programming code forms.

Depending on the task requirements, appropriate display responses to pointing, printing, sketching, bounding, dragging, stretching, inserting, erasing, etc., must occur in real time and be directed in a way natural to the user. A language encompassing these actions must be carefully structured to eliminate ambiguities in interpretation and yet be so natural that the user is rarely uncertain how to accomplish a task. This naturalness and directness allows the user to <u>think continuously about his problem</u>, rather than concern himself with the mechanics of communication.

The large amount of research on automated design will depend increasingly on such intimate contact with machines. Whether the computer system is oriented toward the design of automobiles, bridges, mathematical models, or computer programs, more and more is being demanded of

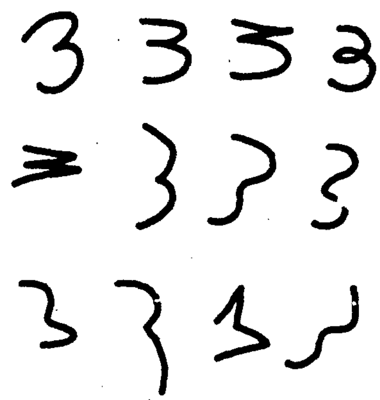

Fig. 2--Some Tracks Recognized as the Symbol "3"

the man-machine communication channel to match the computer's growing ability to quickly answer questions or obey directives.

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